Jet Propulsion Laboratory
California Institute of Technology

Characterization of Low Mass Deformable Mirrors and ASIC driver for high-contrast imaging

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Team

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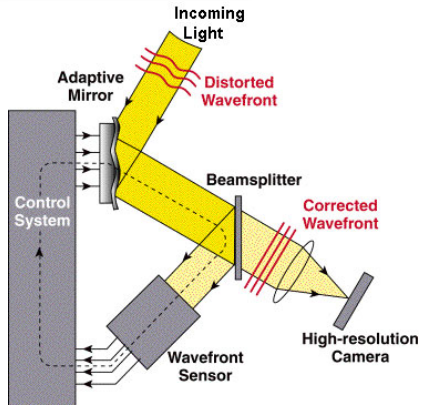
  - Chris Shelton
  - Camilo Mejia Prada
- Microscale – Woburn MA
  - Xingtao Wu
  - Yuqian Wu
  - Li Yao

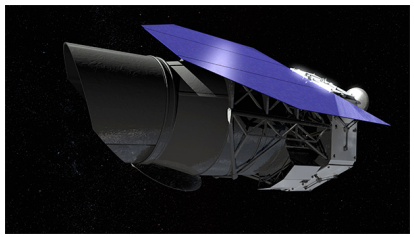
Agenda

- Problems with existing deformable mirrors
- Integrated ASIC-DMs are the Solution
- DM Testing
- Summary

Deformable mirror

- Widely used in ground based adaptive optics system
- Coronagraphs used for exoplanet direct imaging require deformable mirrors (DM) to improve the wavefront quality
- Current state of the art DM electronics are
  - Bulky
  - Connected via 1 wire for every actuator



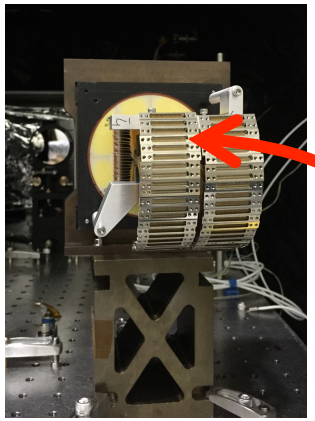


What do we want in a DM?

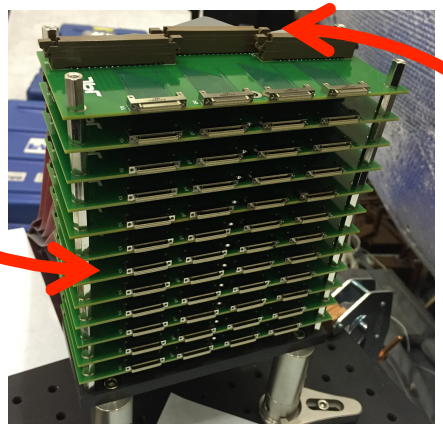
Parameter	BMC	Xinetics	Xinetics	Exoplanet Imaging Requirements
Number of Actuators	64x64	32x32	64x64	64x64
Actuator Pitch (mm)	0.4	1.0	1.8	
Stroke (µm)	3	4	1	~0.5
RMS Surface Error (nm)	0.5	<0.5	6	<1 nm
Actuator Yield	99.4%	100%	100	100%
Driver Step Resolution	14-bit	16-bit	16-bit	Compatible with 5pm
Static Power (W)	10s	10s	100s	Lower the better
Mass/No. of Wires	10s kg / 4k wires	10s kg / 1k wires	100s kg / 4k wires	Lower the better

Current DM electronics is bulky and complex

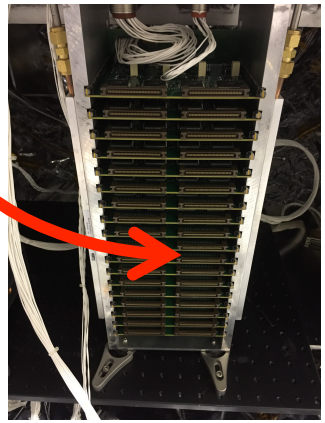
DM



Interface

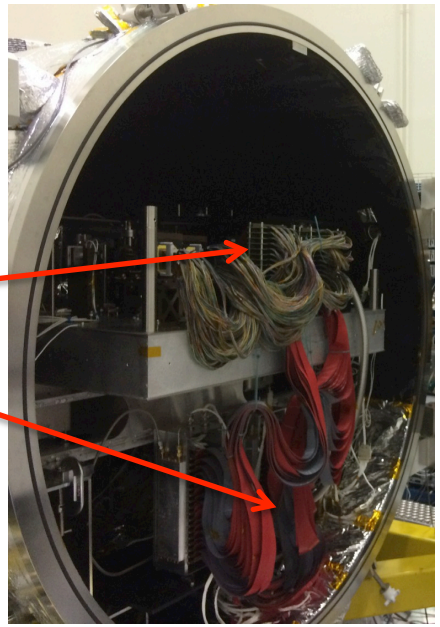


Electronics

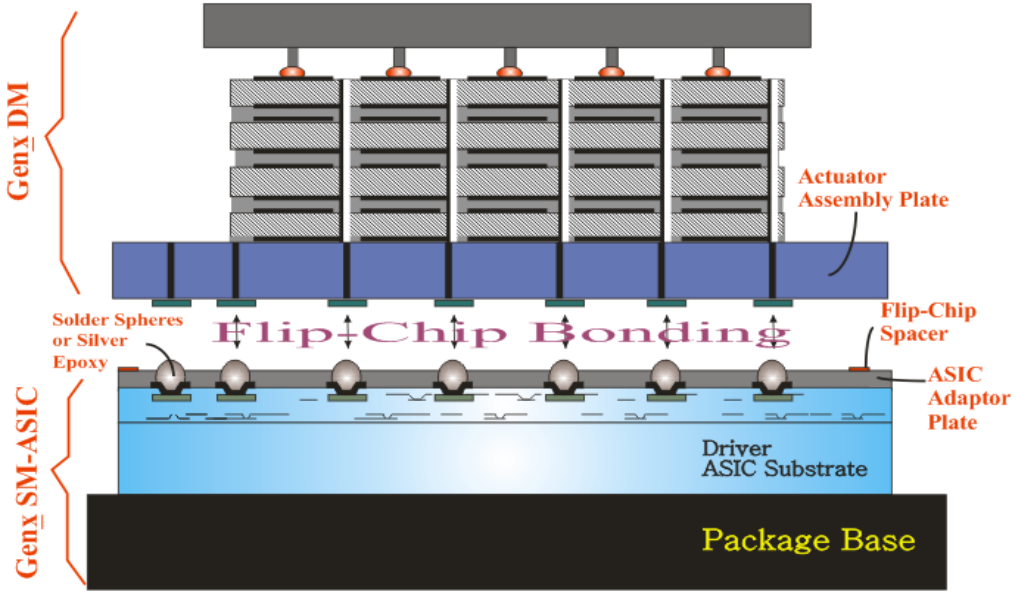


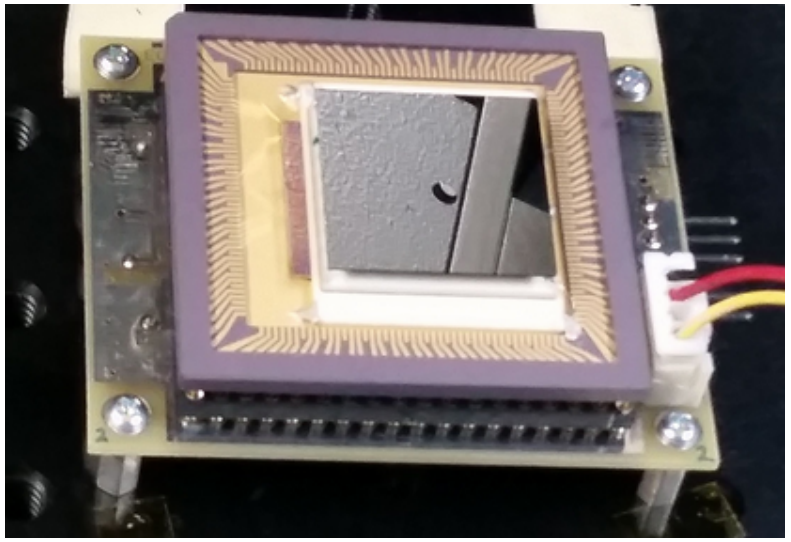
Count all those cables…

(There are two DMs in the picture)



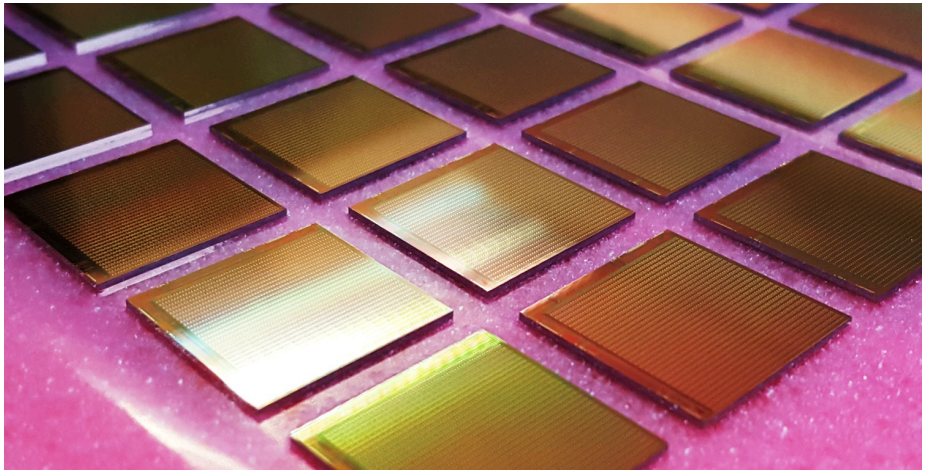
What we want to do is turn all of that into this:



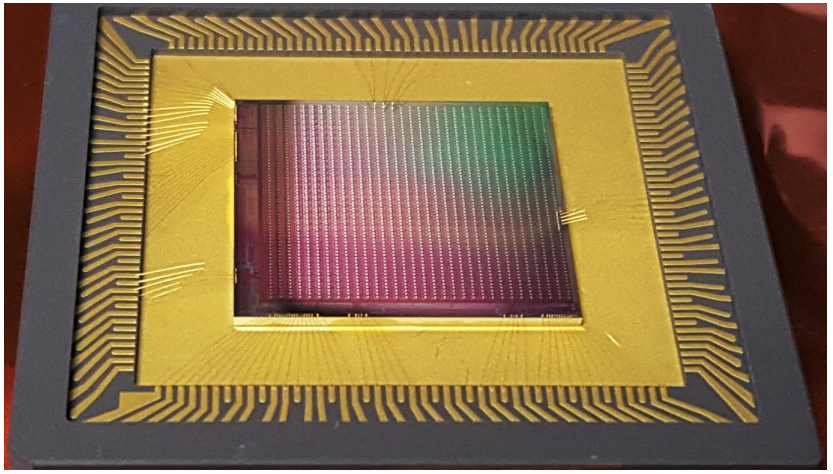


DM-ASIC

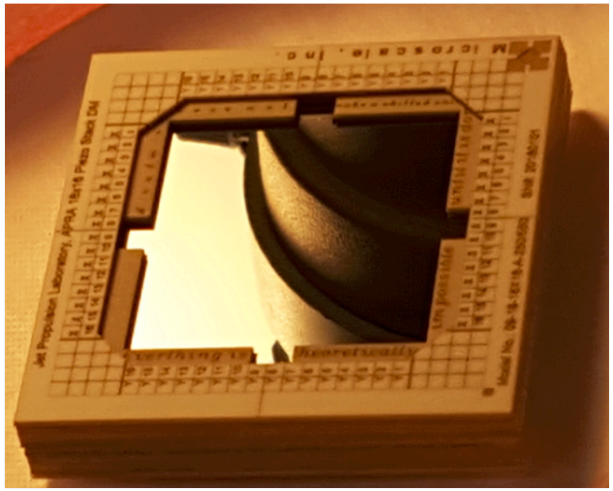
Application specific integrated circuit (ASIC)



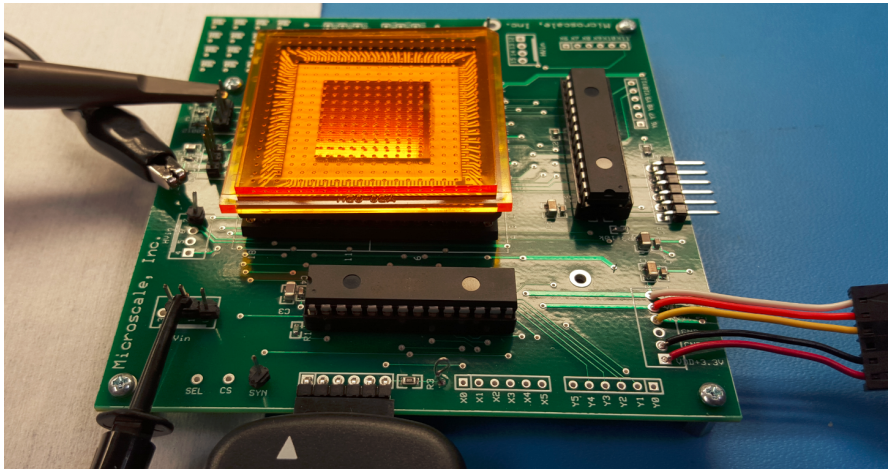
Packaging



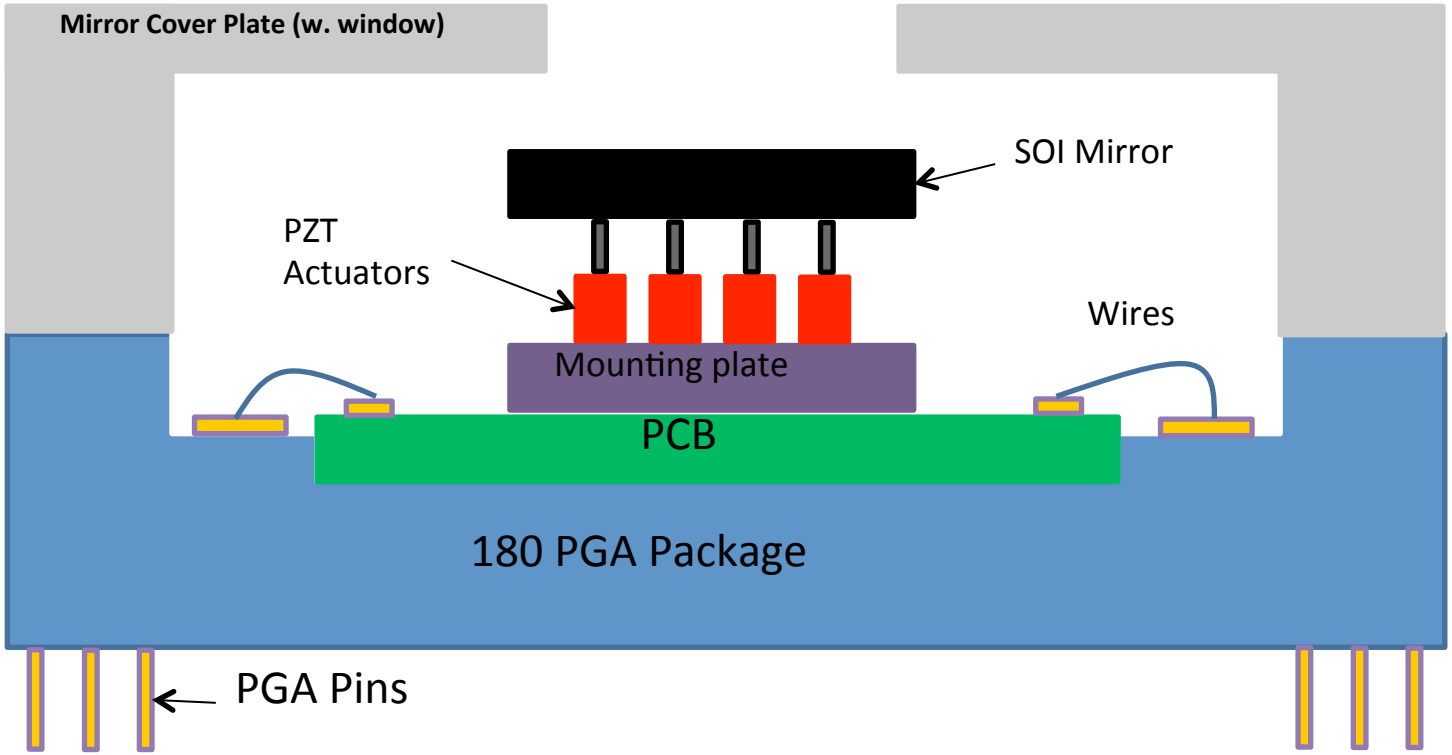
DM



Assembly



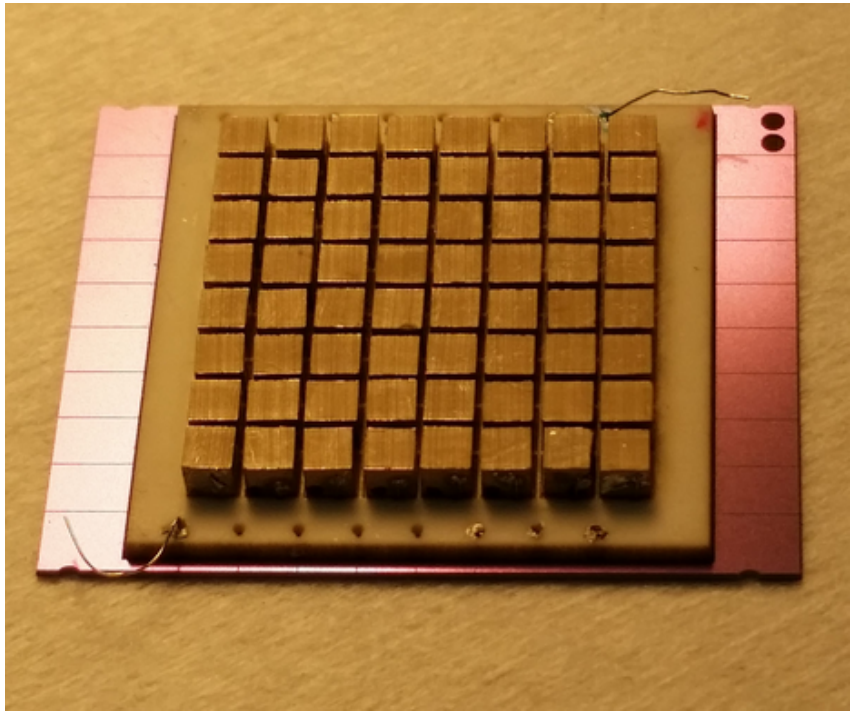
DM Architecture

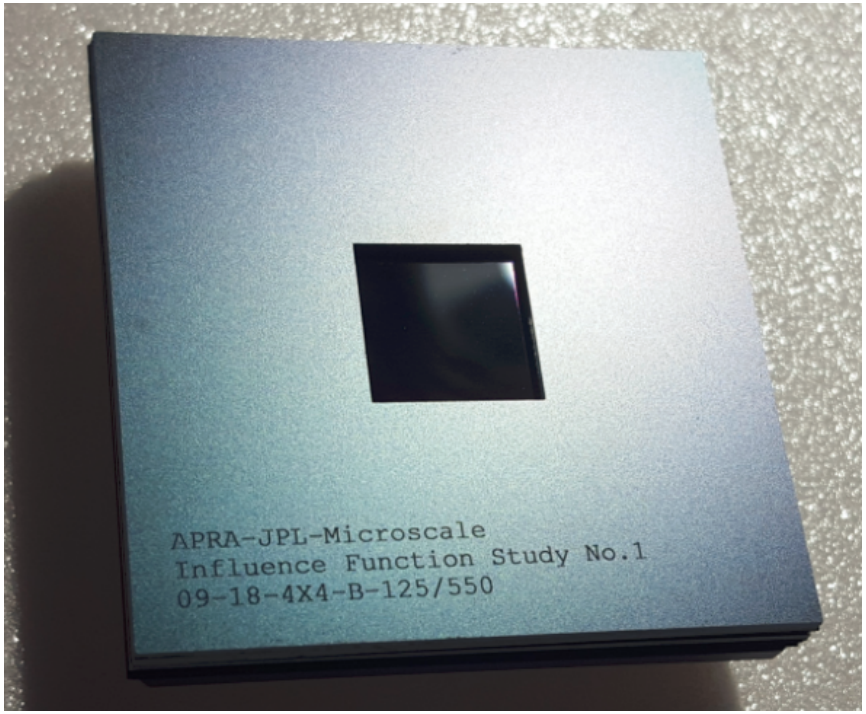


- Microscale has filed for a Patent applied on this architecture

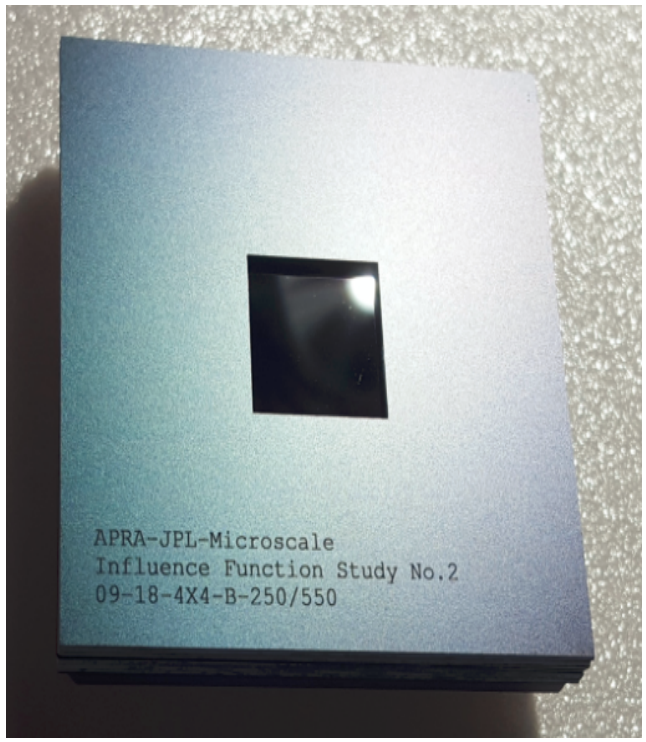
DM Fabrication

without a face sheet



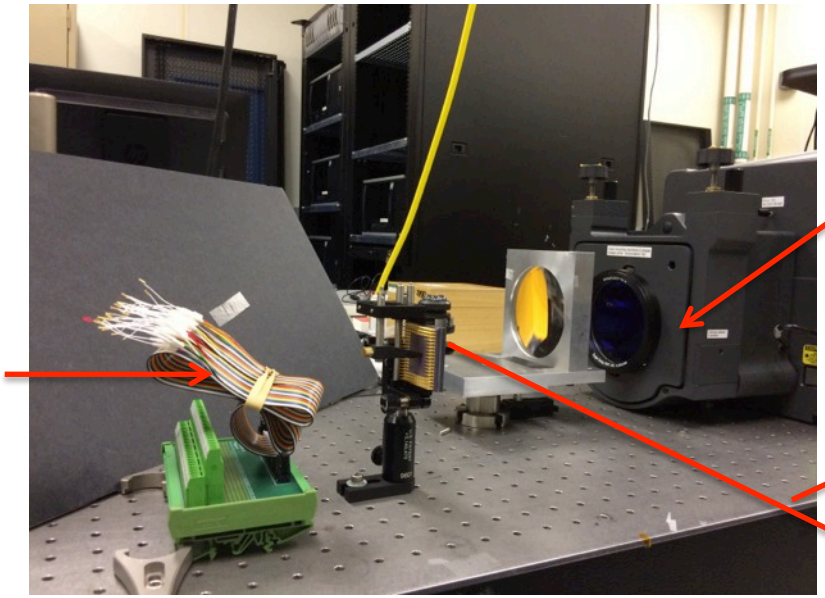


DM capacitance



Pixel (1,4) 13.54nF	Pixel (2,4) 13.46nF	Pixel (3,4) 10.26nF	Pixel (4,4) 11.75nF
Pixel (1,3) 13.59nF	Pixel (2,3) 13.94nF	Pixel (3,3) 12.24nF	Pixel (4,3) 12.53nF
Pixel (1,2) 14.57nF	Pixel (2,2) 9.04nF	Pixel (3,2) 13.17nF	Pixel (4,2) 12.72nF
Pixel (1,1) 13.41nF	Pixel (2,1) 13.76nF	Pixel (3,1) 13.01nF	Pixel (4,1) 13.56nF

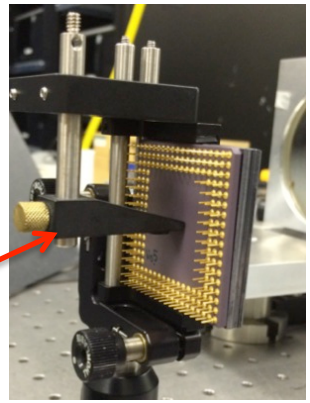
Optical set up



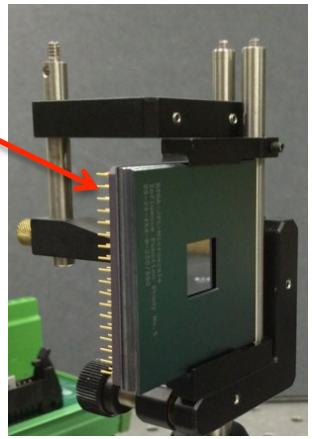
ZYGO

Ribbon cable

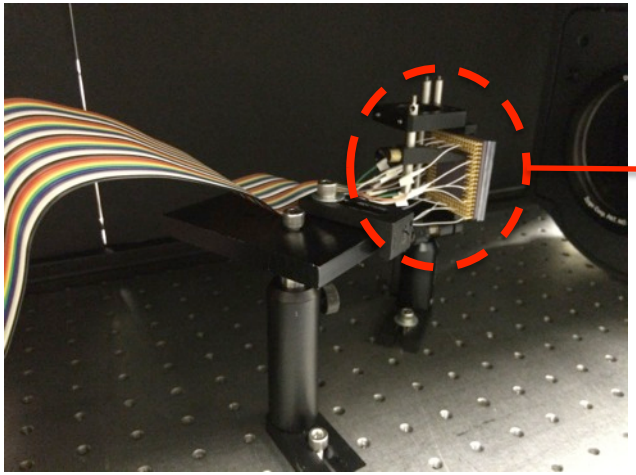
Back

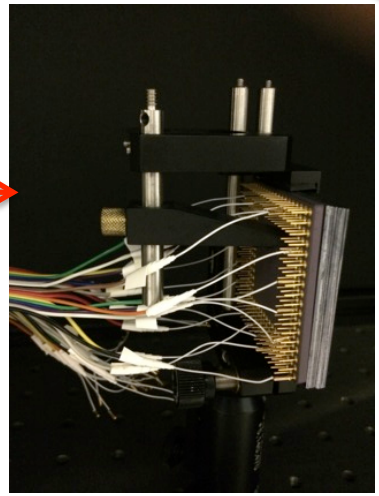


Front



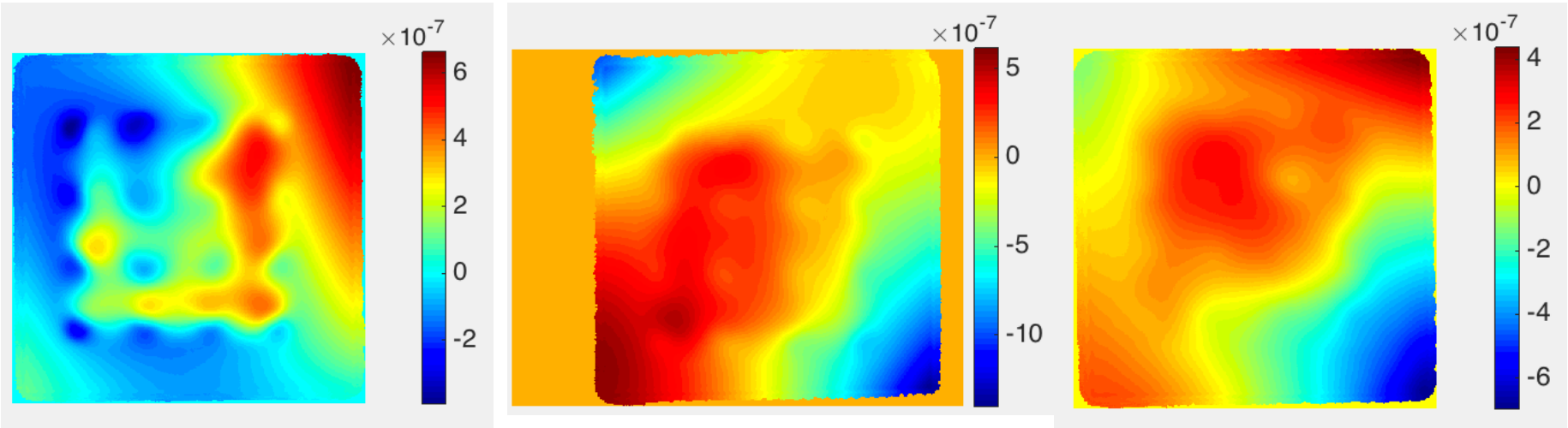
After connection



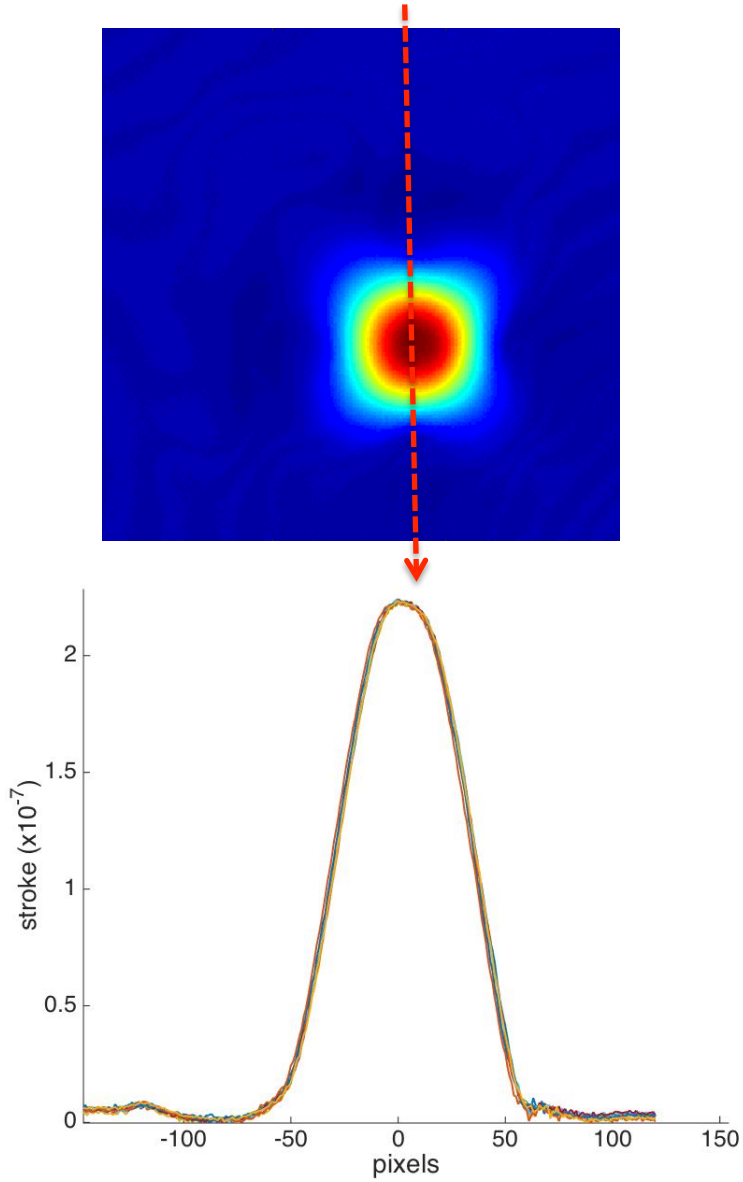


Surface Quality

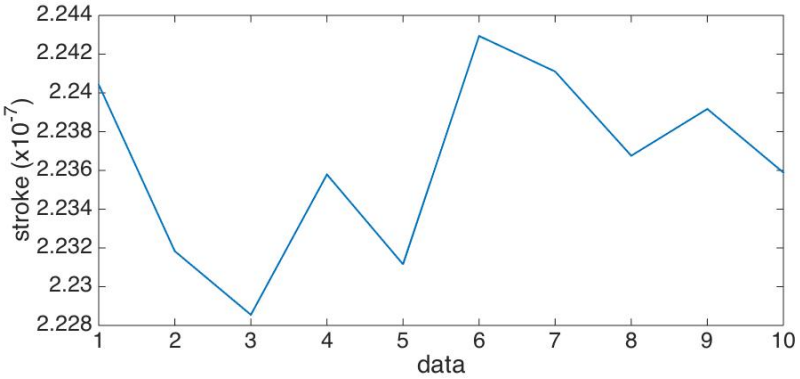
- Too thick, becomes stiff and loses stroke
- Too thin, the surface quality suffers



DM motion is quite stable

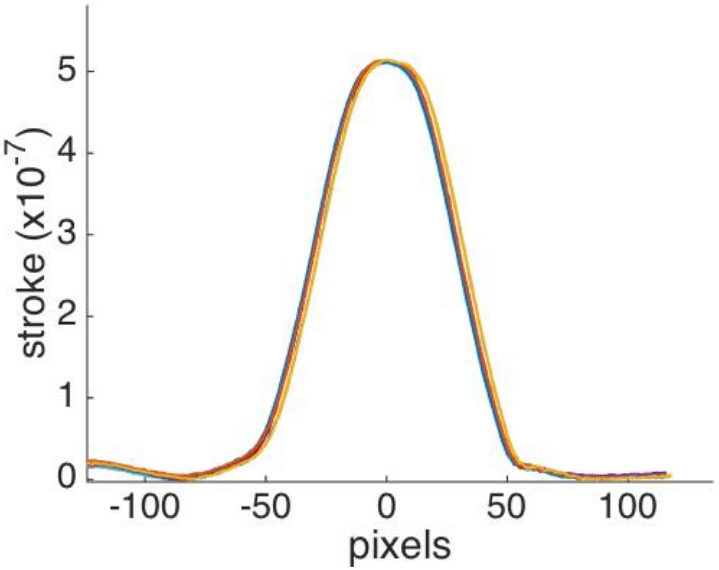


V=12volts

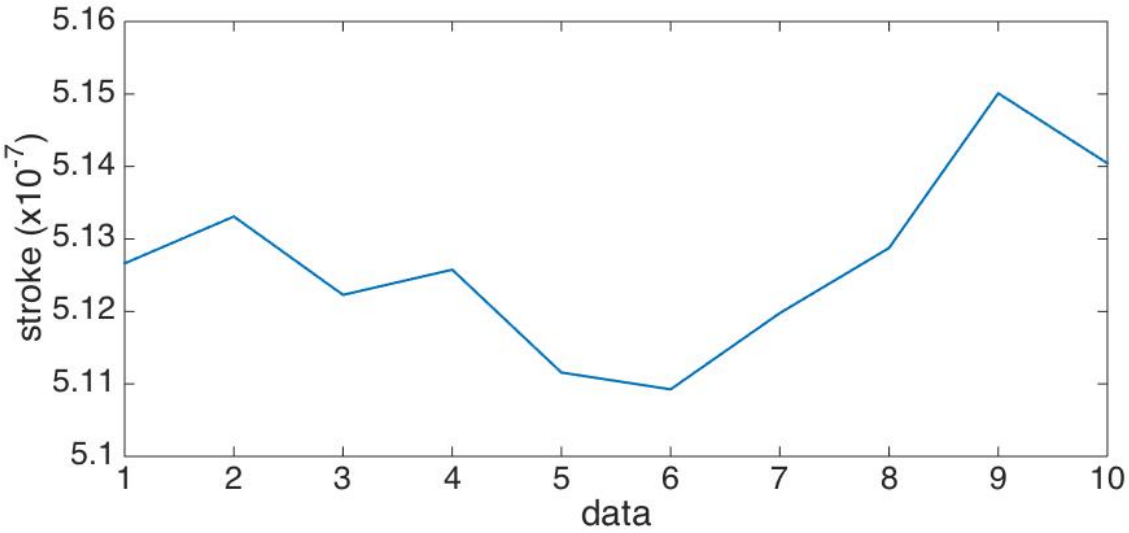


- 10 consecutive measurements with V=12 volts and 30 volts
- Surrounded actuators grounded
- Standard Deviation=0.47 nm

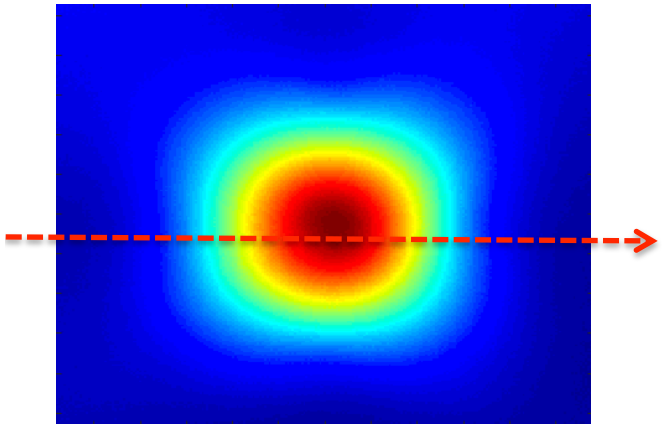
DM actuation is also repeatable

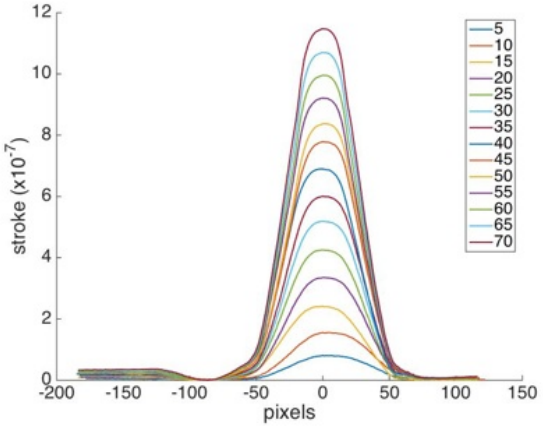


- 10 consecutive measurements after discharging-charging the actuator with 30 volts
- Surrounded actuators grounded
- Standard Deviation=1.2 nm

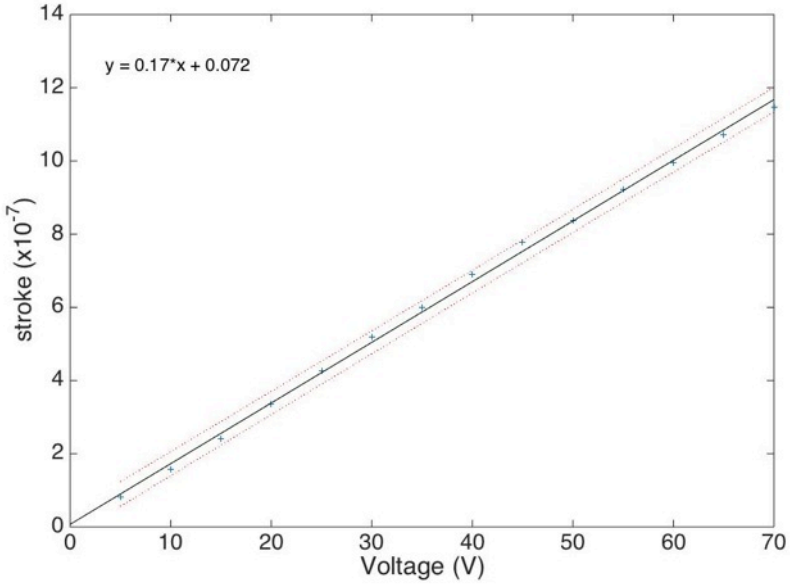


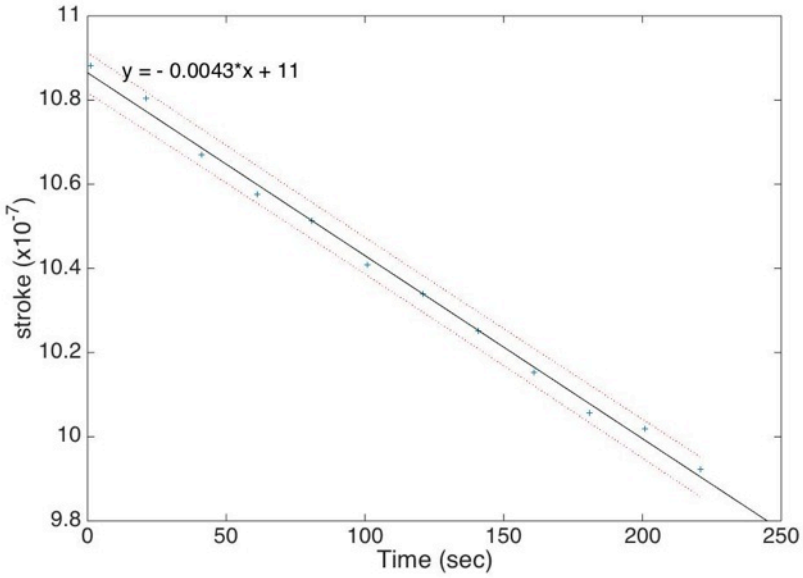
DM motion is also linear





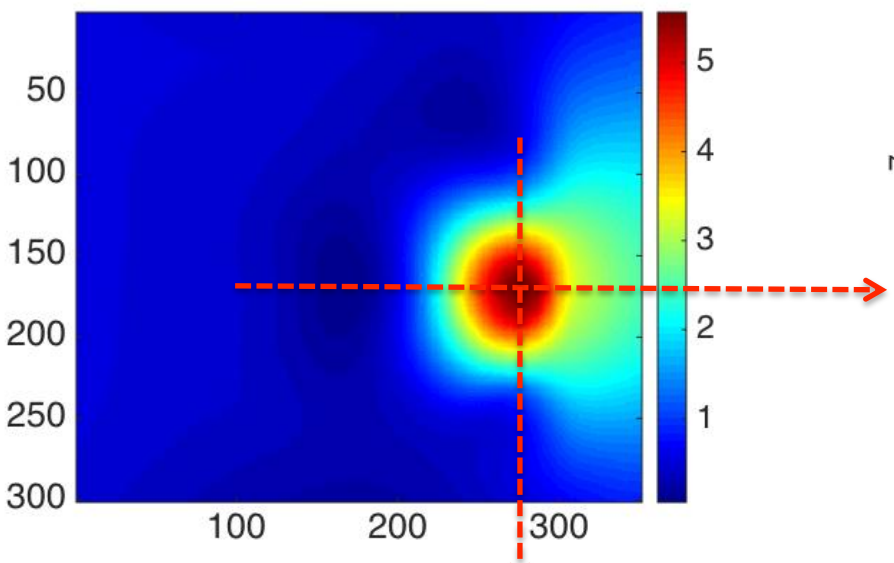
- Gain: 17 nm/volt
- Stroke error +/- 16nm
- Decay at 0.43 nm/sec

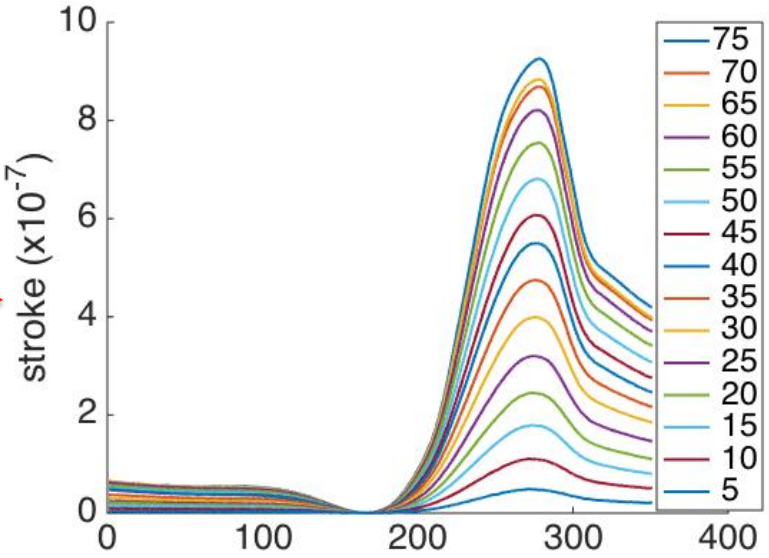


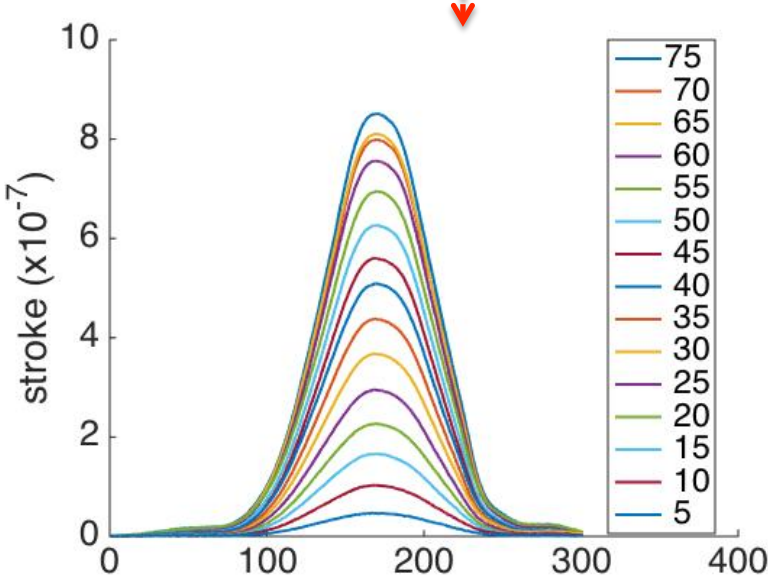


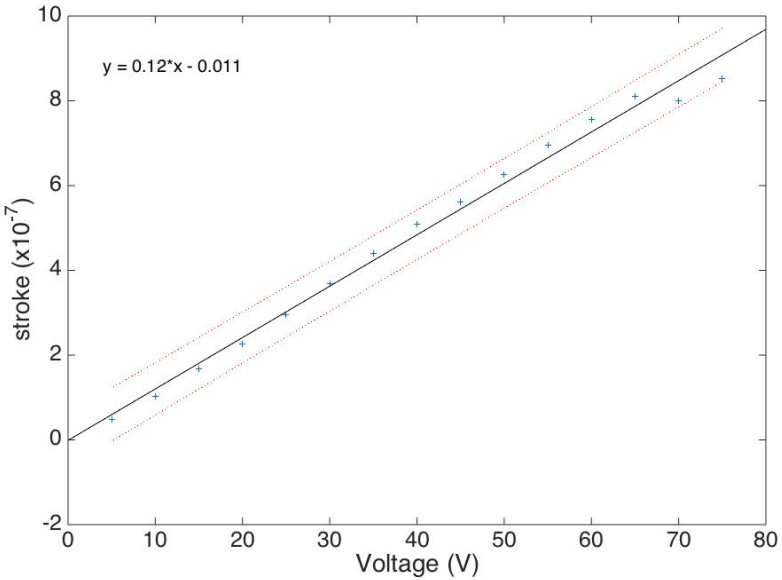
Decay

Edge actuator

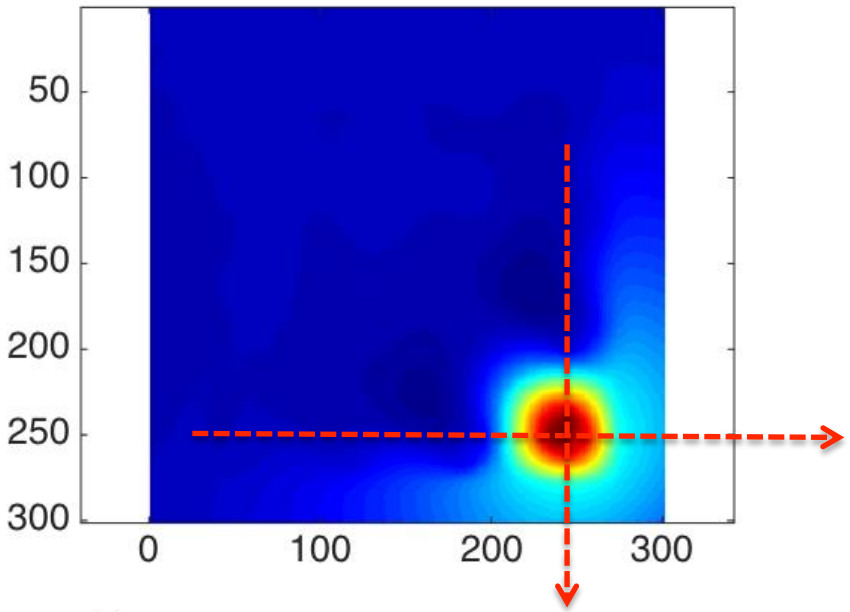


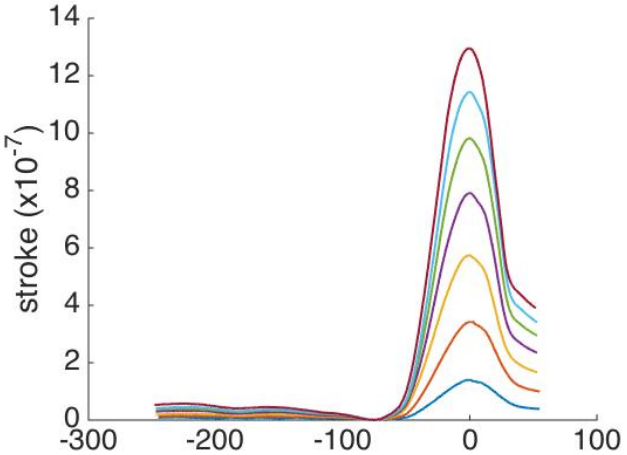


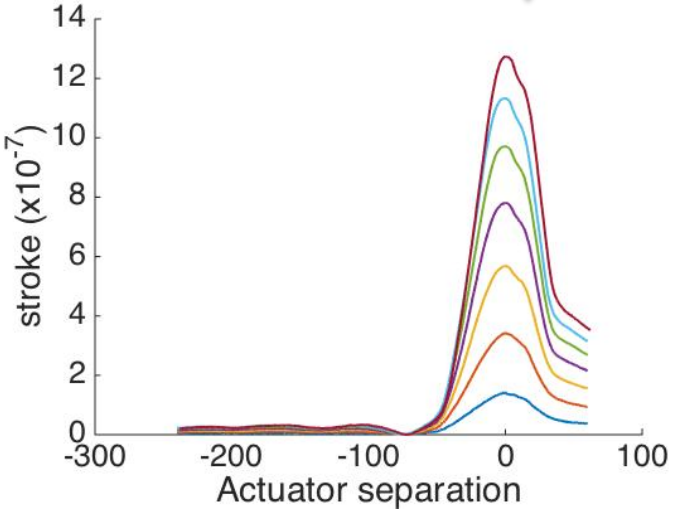


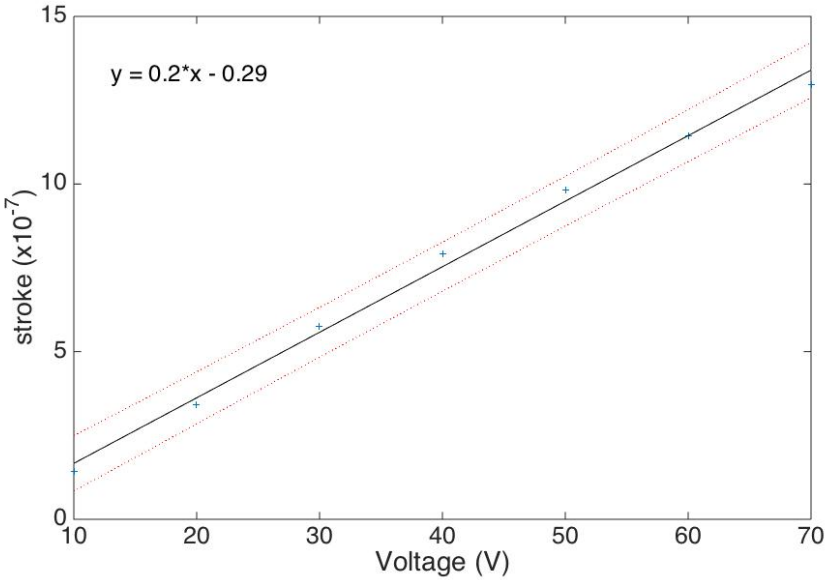


Corner actuator

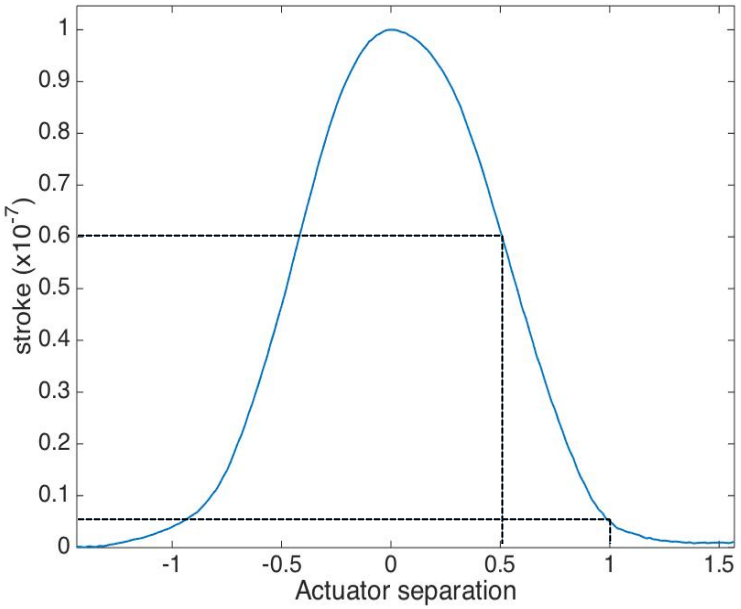




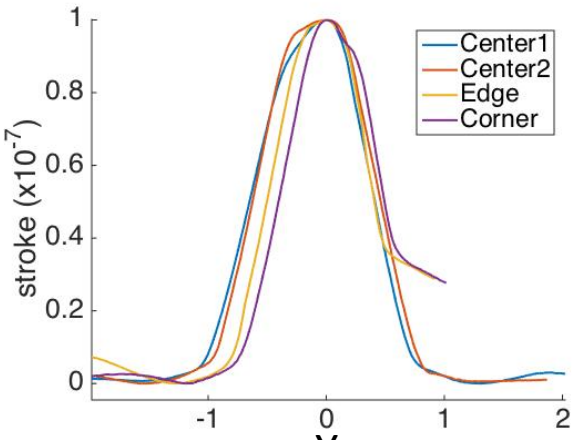




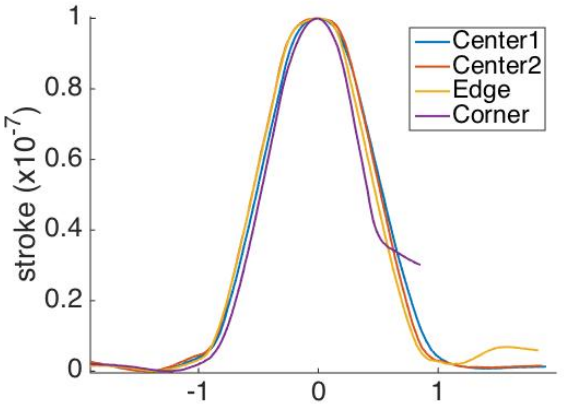
Influence function over different locations



X

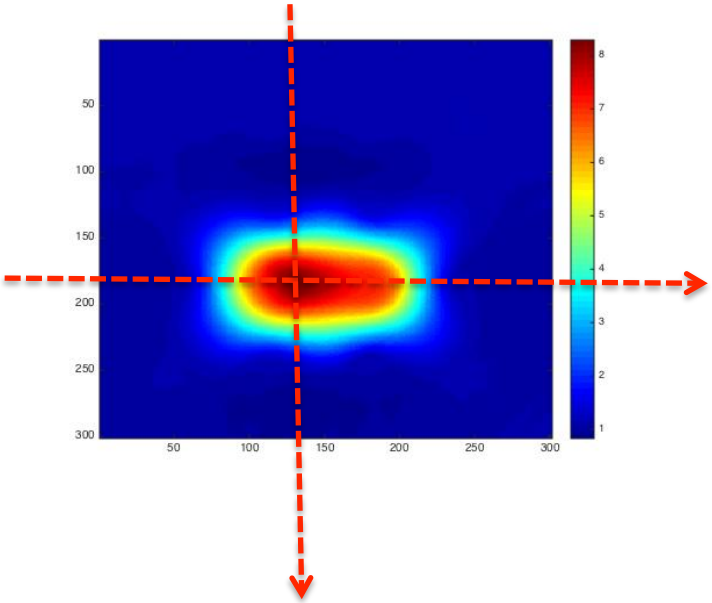


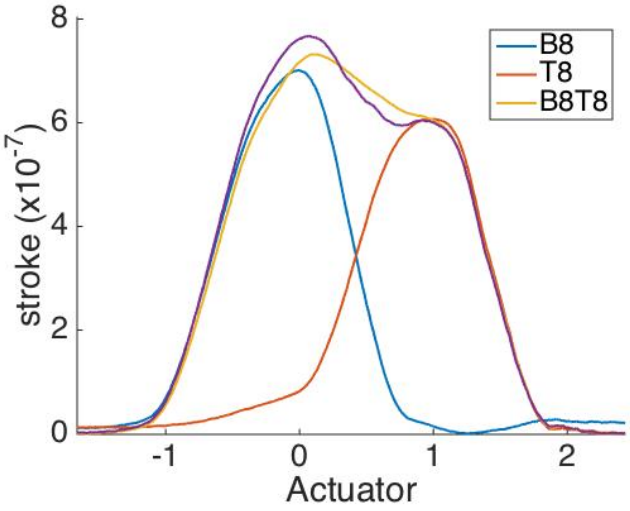
Y

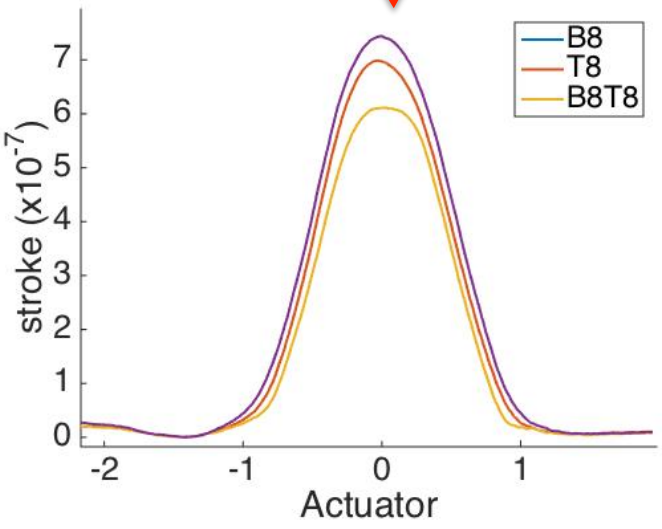


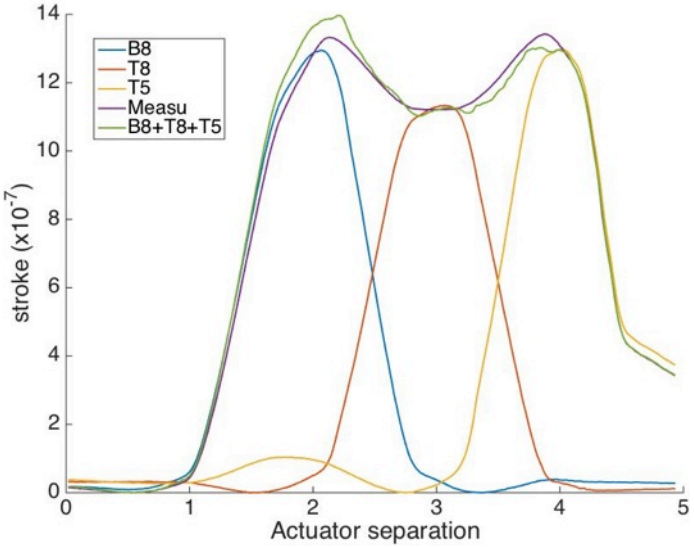
- Influence function coupling factor of 0.0396
- Half point is 0.6118
- The tail of the influence function is different in different actuators

Influence function superposition



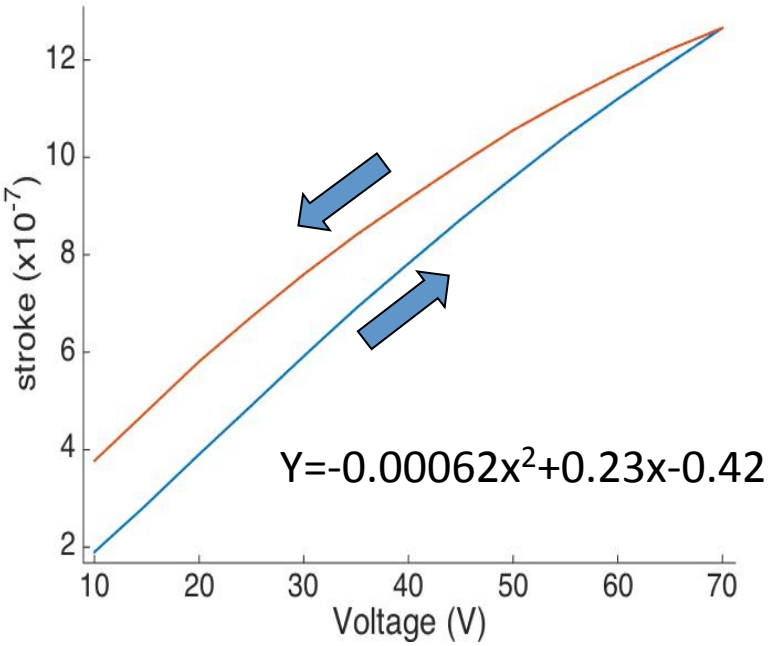


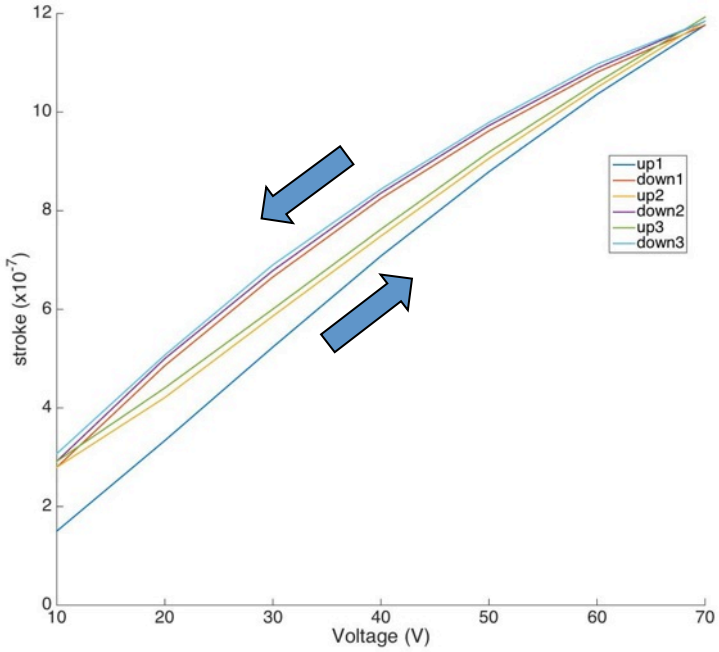




Hysteresis

$Y=-0.0011x^2+0.23x+1.6$

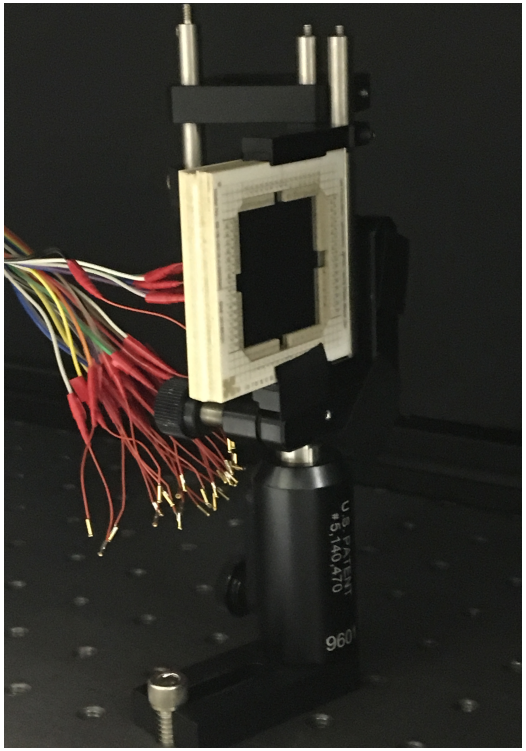




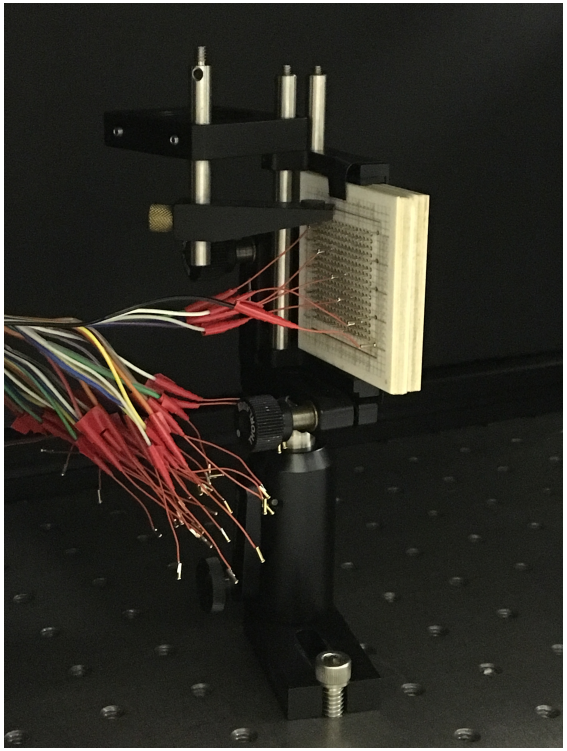
- The device has hysteresis
- Also has a small quadratic component in a cyclic fashion
- Hysteresis is normal for a PZT actuator

Mounting 16x16

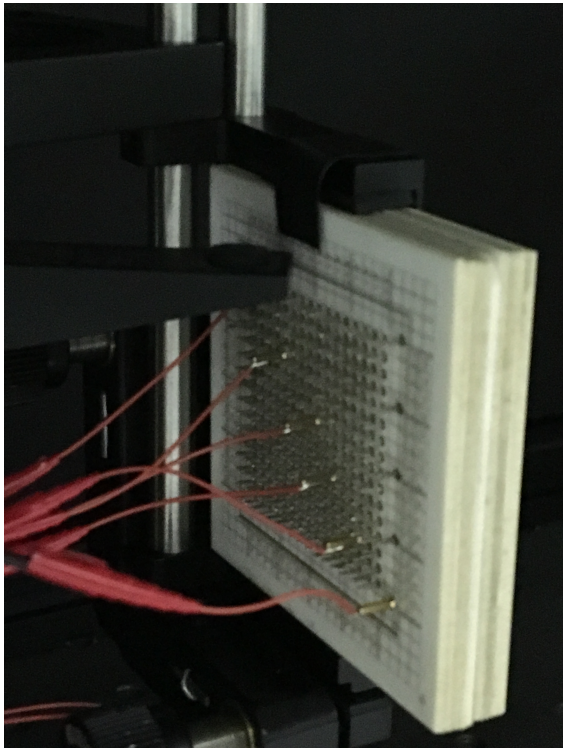
Front



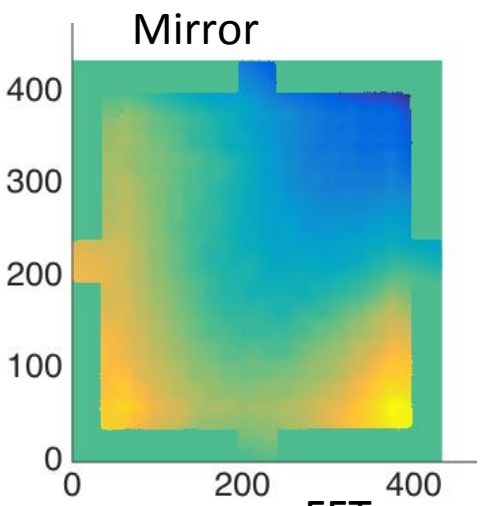
Back

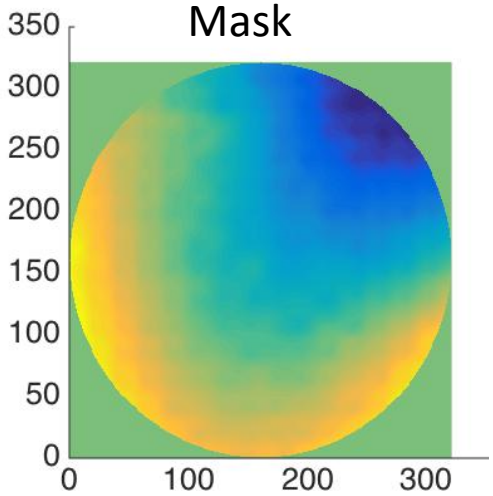


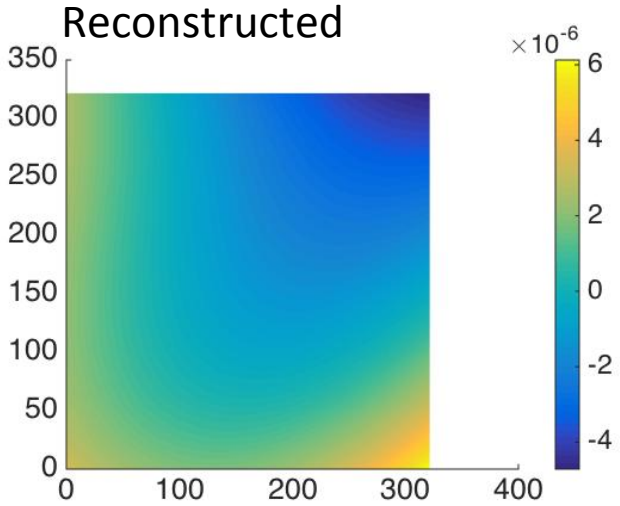
Zoom

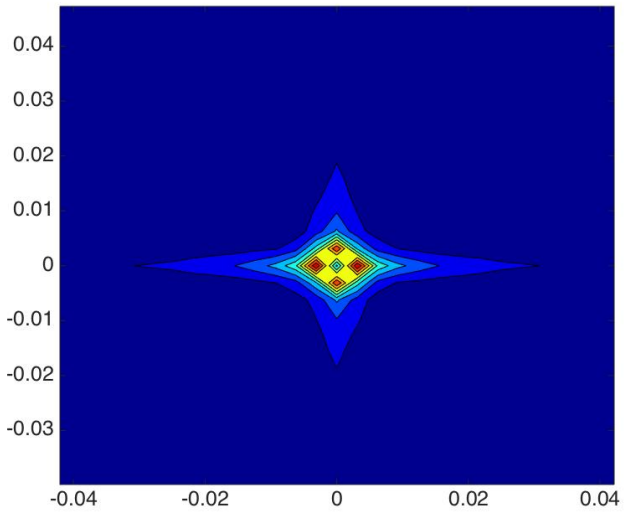


Surface quality



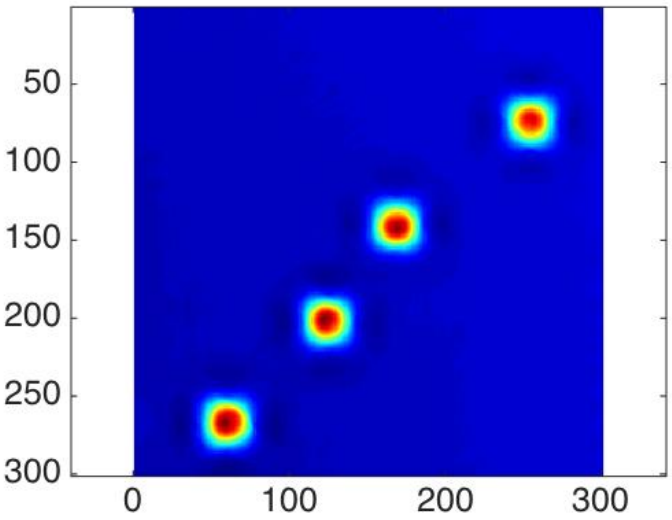


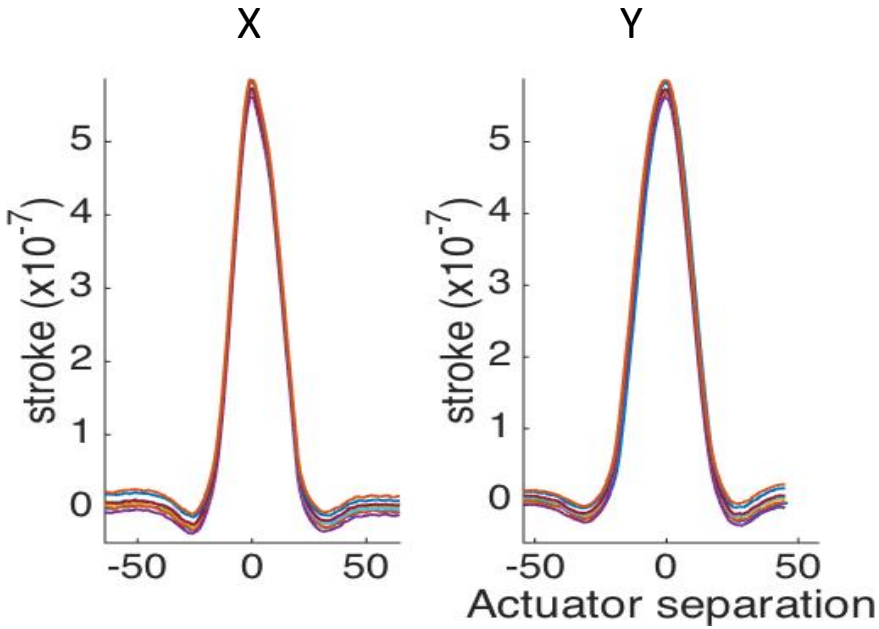




- Zernike =[-0.4635 -0.9149 -0.7419 0.4448 -0.5145 -0.1944 0.0304 -0.0946] microns
- The total PV = 5.7228 microns

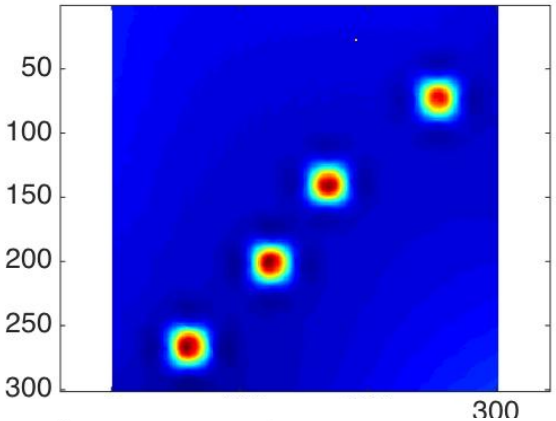
Repeatability and Stability

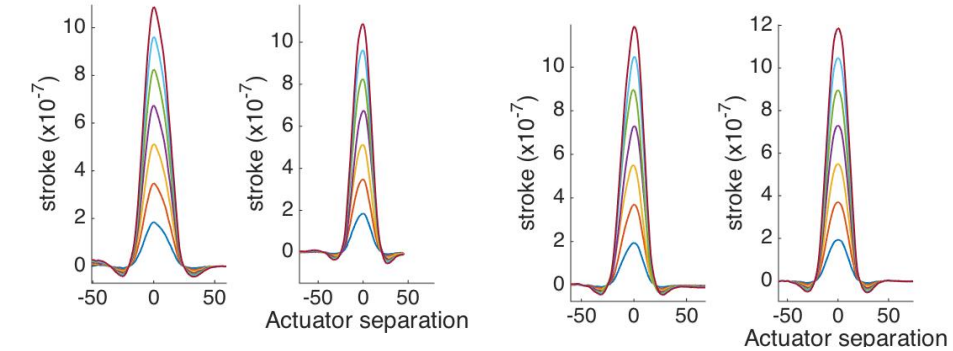


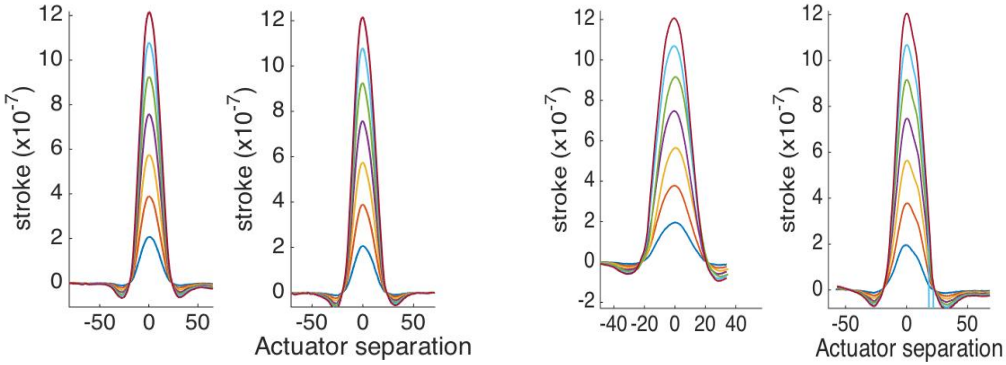


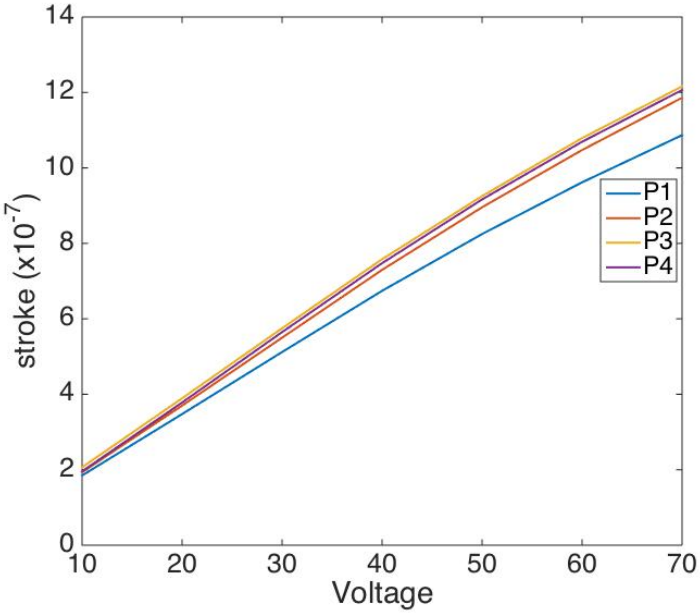
Repeatability:				
Stroke (x10^-7m):	5.7328	6.2503	6.4339	6.4420
Std (x10^-7m):	0.0733	0.0433	0.0316	0.0423
Stability:				
Stroke (x10^-7m):	5.4355	5.9678	6.1357	6.1817
Std (x10^-7m):	0.0697	0.0755	0.0908	0.0974

Stroke



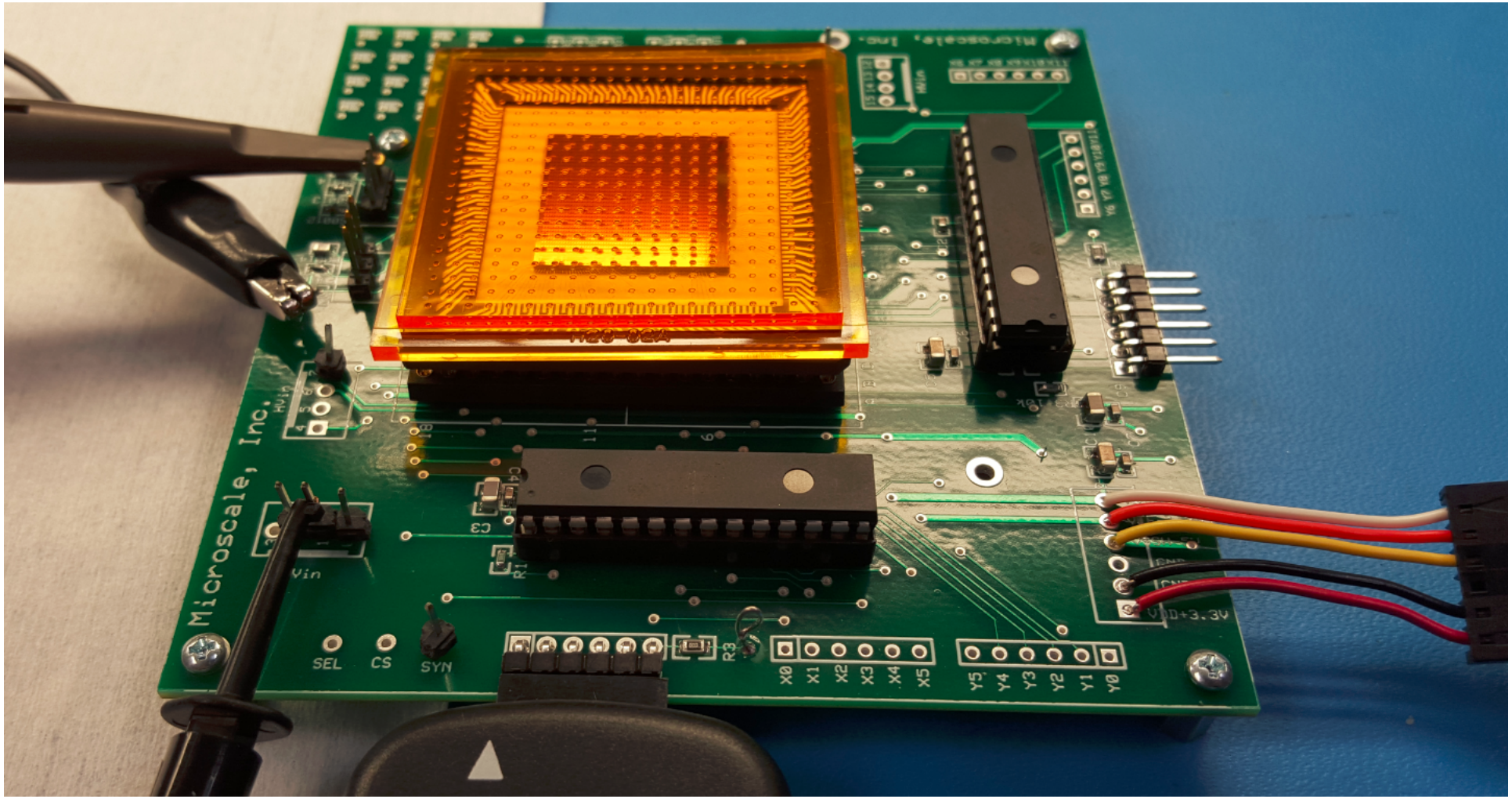






Stroke_1= 15.17 nm/V
Stroke_2= 16.71 nm/V
Stroke_3= 16.99 nm/V
Stroke_4= 17.02 nm/V

SM-ASIC Test Board Video



Summary of PZT-DM Characterizations

- DMs are performing under specifications:

Device	PV(micron)	Capacitance (nF)	Stability(nm)	Gain (nm/V)	Coupling Factor	Half Point	Superpo
09_18_250_550	2.628	12.78+/-1.41	1.72	12.3	0.032	0.58	Y
09_24_75_600	1.052	14.70+/-0.49	1.36	21	0.017	0.428	N
09_24_125_550	2.011	13.21+/-0.61	0.47	17	0.039	0.61	Y
09_24_250_550	1.131	13.55+/-0.81	1.27	12	0.043	0.541	Y

- Stroke has a linear relation up to 75v.
- Hysteresis is present in a cyclic fashion
- Influence function superposition is valid

Summary of ASIC Characterizations

- Control resolution: 0.04mV (20-bit)
- Off leakage current: <4pA
- Off leakage current at HOLD state: <2pA (1nF load)
- Static power dissipation: <4mW (entire 20mm x 20mm ASIC)

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